BY
Vicki L. Almstrum

What Is the Attraction to Computing?

The strongest motivators include a sense of accomplishment from solving problems and programming; the weakest include being captivated by the Web and a passion for playing computer games.

What motivates anyone to study computing? A natural curiosity about the underlying concepts? The field's potential usefulness in other areas? Programming? The ability to advise less technically literate colleagues? Building Web sites or designing systems, including video games? After seeing such preferences cited in articles and books as common knowledge, I began seeking evidence that would support or refute such statements and identify the factors that influence whether or not individuals choose to enter and stay in the field.

In 2002, as I prepared to participate in a panel called "Women, Mathematics, and Computer Science" at the annual SIGCSE Technical Symposium [3], I heard and read a variety of assertions about the factors attracting and repelling students to and from the computing field. The striking lack of evidence supporting most of the assertions prompted me to design a survey to gather data that might shed light on the issue. The survey was exploratory in nature, with the core set of items based directly on statements derived from a variety of sources. I also included items that would allow me to profile the respondents and analyze the data based on various characteristics, including gender and highest academic degree completed.

Nearly 500 computing professionals from the U.S. and other countries completed the survey. The sampling method, though

Illustration by Jean-François Podevin

somewhat informal, quickly put me in touch with a large number of professionals directly concerned with these issues. I recruited participants through several online mailing lists, including Systers (www.systers.org) and the members mailing list of the ACM Special Interest Group on Computer Science Education (www.sigcse.org). I also encouraged respondents to invite their colleagues to participate, thus increasing the international perspective; about 11% of the respondents said they were employed outside the U.S. Highlights of the respondents' demographics included:

- Given this survey was for a panel discussion on women, math, and computer science, most of the respondents (78%) were women;
- Based on the year they reported finishing their pre-college education (assuming it occurred about age 18), the average age of respondents was 39, with good representation in all age categories, from under 25 to over 60;
- Nearly 90% reported having at least a bachelor's degree, over 50% a master's degree, and 37% a doctoral degree;
- Over 50% were involved in education, either as students (17%) or instructors (36%). About 33% reported their principal job responsibility was in industry, including in software development, technical management, and consulting; and
- Over 50% reported having taught at the college level, with 24% teaching both computing and mathematics courses, 28% teaching only computing courses, and 3% teaching only mathematics courses.

Details of the development and content of the survey, along with the ongoing results from my investigation, are available at www.cs.utexas.edu/users/csed/sigcse/2002/women-math-cs/.

Attitudes Toward Math and Computing

One section of the survey focused on respondents' attitudes toward mathematics and computing by asking how strongly they agreed with several statements. About 75% of the respondents indicated that a good understanding of mathematics is important for computing professionals; the same percentage replied that this understanding is also important for being able to appreciate the concepts of computing. Only 40% expressed a preference for programming courses over theoretical courses. Practically all respondents agreed that mathematics is a key foundation for computing. Only 2% disagreed with the statement: "A good understanding of mathematics helps one better understand and appreciate the concepts of computer science."

Three statements focused on perceptions of the role of math anxiety in undergraduate student success in computing. Only 15% of the respondents agreed with either of the two statements (one about women, the other about men): "Undergraduate [women/men] who suffer from math anxiety cannot succeed in a computing field." The nearly perfect positive association between responses to these statements suggests a view that math anxiety can affect a student's ability to succeed in computing, irrespective of gender. Responses to the statement: "At the undergraduate level, men are as likely to suffer from math anxiety as are women," showed little relationship to the responses to any of the other statements related to math anxiety. The patterns of responses to the math anxiety statements suggest a relationship between respondents' personal experience with math anxiety and their opinions about the likelihood of success for both women and men at the undergraduate level.

About 80% of the respondents agreed with statements concerning whether they enjoyed mathematics or were good at it. The responses shared substantial negative association with the responses to statements about whether undergraduate men and women suffering math anxiety are able to succeed in a computing field. There was also a positive association between responses about enjoyment of and personal skill in mathematics to the statement about whether men and women are equally likely to experience math anxiety.

Attraction Factors

To investigate why individuals choose computing as a profession, I included in the survey a set of 18 possible attraction factors suggested by the literature, refining them through a series of pilot runs with earlier versions of the survey. Respondents rated each such factor as to whether it had been important, minor, or irrelevant in their personal histories.

The two most influential factors influencing whether or not respondents pursued computing were "the sense of accomplishment that comes from solving the problem" and "using a computer to solve problems," as cited by 96% and 93% of the respondents, respectively. The least-cited factor was "a passion for playing computer games," influencing only 18% of the respondents. The second least-cited attraction factor was "captivated by the Web," influencing only 30% of the respondents. Each of the other 14 attraction factors was cited as influential by over 50% of the respondents (see the table here).

In analyzing the responses, a complex pattern of strong, mostly positive, associations emerged among the 18 factors. To search for relationships among them, I built a descriptive model using the technique of primary component analysis, a statistical method related to factor analysis [4]. Using these techniques, a good model should result in a small number of underlying dimensions, each composed of two or more of the observed variables—in this case, the attraction factors—such that the dimensions have a meaningful interpretation. The primary component analysis resulted in a model of four dimensions, with each of the 18 factors contributing to various degrees across these dimensions.

Interpreting this model, I determined which factors contributed most to each dimension. The combinations of factors led me to label the dimensions as follows (adapted from dictionary.com):

Dimension	Weight*	Factors from Survey	Influence†
Benefit	[0.84]	*creating something that will benefit others*	85%
	[0.82]	*using the computer to solve problems*	93%
	[0.77]	*usefulness in supporting other areas/fields*	85%
	[0.74]	*sense of accomplishment from solving problems*	96%
	[0.55]	*ability to create "exact" solutions*	69%
Science	[0.87]	*logic involved*	90%
	[0.72]	*mathematics at its foundations*	60%
	[0.67]	*beauty and elegance one can achieve*	76%
	[0.56]	*programming*	81%
Experiment	[0.92]	*prospect of something to play with*	76%
	[0.87]	*possibility of experimentation*	85%
	[0.81]	*"gadgetry"*	55%
	[0.66]	*having something to push to its limits*	55%
Vanguard	[0.89]	*captivated by the Web*	30%
	[0.70]	*passion for playing computer games*	18%
	[0.65]	*being in a position to advise the less technically literate*	60%
	[0.59]	*being on the cutting edge*	69%
	[0.47]	*linguistic foundations*	52%

* Standardized regression coefficient, which is functionally related to the partial or semipartial correlation between a variable and the dimension when the other dimensions are constant [3]. A value closer to 1.0 indicates a stronger contribution to that dimension.
† Reports the percent of respondents choosing the corresponding factor as either an important factor or a minor factor in attracting them to computing.

Factors attracting survey respondents to computing.

Benefit. Something promoting or enhancing well-being;
Science. The observation, identification, description, experimental investigation, and theoretical explanation of phenomena;
Experiment. Trying something new, especially in order to gain experience; and
Vanguard. The foremost or leading position in a trend or movement.

The contributing factors generally made sense in the context of the dimensions. The only factor for which placement was somewhat puzzling was "linguistic foundations," which had its greatest loading in the Vanguard dimension, though the loading was also the lowest maximum among the 18 factors. Had I tried to predict the placement of this factor in advance, I would have placed it in the Science dimension. Perhaps the phrasing of the term led to inconsistent interpretations by the respondents.

Composite Profile

The composite profile of survey respondents helps guide interpretation of the survey results. Because about 33% of them classified their principal job responsibility as educational and about 33% gave their current employment responsibility as being in an industrial setting (such as software developer or manager), the data did not appear overly focused on either education or industry. However, nearly 80% of the respondents were women. Because extensive research indicates important differences in how men and women become interested in, enter, and remain in the computing field (see, for example, [2]), we can now ask whether the four dimensions of attraction to computing would hold in professional and educational settings with greater proportions of men. Future work is needed to validate the four-dimensional model by considering whether it holds for various subgroups, as well as for the general population.

The four-dimensional model does have potential for explaining why individuals are attracted to the computing field. Considering the composite scores, respondents with higher scores on the Experiment dimension also had higher scores on the Benefit and Vanguard dimensions. Science had the weakest associations with the other three dimensions, indicating that when individuals viewed the Science dimension as important, they were less likely to view the other dimensions as important, too. This outcome suggests that the Science dimension is a more unique rationale for entering computing than are the other three dimensions.

These results suggest that computing professionals have a strong sense of the field's mathematical roots and tend to be unhampered by math anxiety. It also appears that a love of programming, commonly cited as a key reason for entering the field, may not in itself be an especially strong motivator. Instead, the derived dimensions of Experiment, Benefit, and Vanguard may better explain what attracts most people to computing.

THE RESULTS PROMISE TO HELP TEACHERS, CURRICULUM DESIGNERS, AND ADMINISTRATORS FINE-TUNE THE WAYS THEY RECRUIT AND RETAIN TALENTED STUDENTS IN THE COMPUTING DOMAIN.

Implications for Students and Teachers

What do these results imply for students and teachers of computing courses? The relative strengths of the four dimensions in the attraction model suggest curricular strategies teachers can use to help encourage individual students to consider entering or continuing in the computing field.

Benefit (strongest motivator). The Benefit dimension was the strongest motivator for the respondents in the survey, with four of the five component factors selected as influential by 85%–96% of the respondents. The most influential factor within this dimension was "the sense of accomplishment that comes from solving the problem." A curriculum that emphasizes the factors of the Benefit dimension is thus likely to encourage people to consider entering and staying in the field.

Science (second motivator). The Science dimension emerged as the next-strongest motivator. The two most influential component factors were "the logic involved" and "the programming." The other two factors—"the beauty and elegance one can achieve" and "the mathematics at its foundations"—were influential factors for 75% and 60% of the respondents, respectively. A curriculum blending an appreciation of the underlying theory with an understanding of the practical skills of programming would support this dimension.

Experiment (relatively weak motivator). The Experiment dimension, a relatively weak attractor for these respondents, had as its most influential factor "the possibility to experiment." The two component factors—"gadgetry" and "having something to push to its limit"—were influential factors for just over 50% of the respondents. This suggests that a computing curriculum with a strong experimental aspect might help attract people to computing and keep them in the field, but that "tinkering" and "tweaking" activities may have less appeal. On the other hand, [2] observed that boys/men tend to tinker with ideas that interest them, while women tend to focus on concepts and skills that will help them in class. This suggests that for some people, tinkering may help them better understand concepts not presented in class. Thus, while fostering a willingness to experiment and try new things may not initially attract people to computing, engaging in these practices may make a difference in some students' success over time.

Vanguard (least important motivator). The least important of the four dimensions was the Vanguard dimension. Among its five component factors, the two strongest were "being on the cutting edge" and "being able to advise less technically literate individuals." In the context of a computing curriculum, this suggests that including concepts from the forefront of technology and making them explicit can help attract and retain students. The two weakest factors in this dimension were "captivated by the Web" and "a passion for playing computer games," suggesting that such specific current activities may not be primary motivators in the long term.

Conclusion

A key insight from this exploratory study is that much remains to be done. The four-dimensional model of attraction to computing suggests priorities for curricular elements that might pull individuals into the field. At the same time, these dimensions may play different roles in different segments of the population: female vs. male, academic vs. industry, experienced vs. novice. The respondents' written comments suggest that additional factors, including money, opportunity, and job security, also attracted them to computing.

To build on this work, it would make sense to redesign the survey and distribute it more broadly in several target settings; for example, the wording of certain factors could be improved and additional factors added. Another issue is the reliability of self-reports regarding motivating factors from earlier in the respondents' lives; perhaps some respondents answered in ways they wish had been true at the time they made their decisions concerning their pursuit of computing.

The results, including the model of attraction to computing, promise to help teachers, curriculum designers, and administrators fine-tune the ways they recruit and retain talented students in the computing domain. The model may also suggest how to advise young people who are considering entering, staying in, or even leaving the field. **C**

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Vicki L. Almstrum (almstrum@cs.utexas.edu) is a lecturer in the Department of Computer Science at the University of Texas at Austin.